The Pharma Innovation Journal 2023; 12(7): 139-148

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2023; 12(7): 139-148

www.thepharmajournal.com
Received: 04-05-2023
Accepted: 06-06-2023

Ashok S Dambale
Assistant Professor, Department of Agronomy, College of Agriculture, Selu (V.N.M.K.V, Parbhani, Maharashtra, India

Jogesh Goswami
Professor, Department of Agronomy, AAU, Jorhat, Assam, India

KK Sharms
Principal Scientists, AICRP on Forage Department of Agronomy, AAU, Jorhat, Assam, India

K Kurmi
Professor, Department of Agronomy, AAU, Jorhat, Assam, India

KN Das
Professor, Department of Soil Science, AAU, Jorhat, Assam, India

R Das
Professor, Department of Crop physiology, AAU, Jorhat, Assam, India

Corresponding Author:
Ashok S Dambale
Assistant Professor, Department of Agronomy, College of Agriculture, Selu (V.N.M.K.V, Parbhani, Maharashtra, India

Effect of different K management practices on growth and yield parameters of black rice (*Oryza sativa* L.) under system of rice intensification

Ashok S Dambale, Jogesh Goswami, KK Sharms, K Kurmi, KN Das and R Das

Abstract
An agronomic investigation was carried out at Instructional-cum-Research Farm of Assam Agricultural University, Jorhat, Assam, during *kharif* season of 2019-20 and 2020-21 toassess the growth and yield parameters of black rice under organic ecosystem of northeast India. The topography of experimental field was uniform and fairly levelled. The farm is located at 26° 47'N latitude and 94° 12'E longitudes at an elevation of about 86.6 m above mean sea level. The experiment was laid out in randomized Block Design (RBD) with three replications. The soil of experimental plot was brownish to yellowish brown color with fair drainage and sandy loam in texture with acidic in pH, low in available nitrogen, phosphorous but medium in available potassium. The experimental data recorded during both successive years revealed that the growth, yield attributes and yield of organic black rice was significantly influenced by different K management practices. Among the different growth parameters *viz.*, plant height, leaf area index, no. of leaves, root volume, and dry matter accumulation at different stages were observed to be significantly higher with the application of RDK through banana pseudo stem vermicompost + mustard oil cake @ 20 kg ha^{-1} *i.e.* treatment T_8, while the lowest values were recorded under the control treatment T_1. In case of yield and yield attributing characters like, no. of panicles (m^{-2}), panicle length (cm), and test weight (g) were found to be superior in respect of almost all the studied parameters under the treatment T_8. The highest no. of panicles (m^{-2}) 294.10, 305.20, panicle length 27.49 (cm), 28.87 (cm), and test weight 24.48 (g) 24.56 (g), respectively during 2019 and 2020 were also found highest with treatment T_8. The highest grain yield 23.99 q ha^{-1}, 25.05 q ha^{-1} and straw yield 45.02q ha^{-1}, 47.12 q ha^{-1} were registered with the treatment T_8 *i.e.* RDK through banana pseudo stem vermicompost + mustard oil cake @ 20 kg ha^{-1} during 2019-20 and 2020-21, respectively.

Keywords: Black rice, bio inputs, SRI, ITK, growth attributes, yield studies, potassium

1. Introduction
Rice (*Oryza sativa* L.) is the staple food for more than half of the world's population. In India, it is cultivated over an area of 43.86 million hectares with 117.47 million tonnes of production (DAC&FW, 2019-20). It plays a significant role in the nation's economy. Rice is of different types based on the size of grains, texture, aroma, maturity duration, growing environment and colour (polished, black, red, purple and brown). The colored rice varieties are considered to have numerous health benefits. Black rice (*Oryza sativa L. indica*), is a special cultivar of rice which contains remarkably high anthocyanin pigments in the aleurone layer than white and red rice which account for its violet or dark purple colour (Hou *et al*., 2013) [42]. Black rice is locally known as 'Chakhao', means delicious rice in Manipuri language is cultivated mainly by Meitei farmers of Manipur. There are four landraces of black rice in Manipur which includes Chakhao amubi, Chakhao angouba, Chakhao poireiton and Chakhao pungdol amubi. Black rice is almost six times richer in antioxidant activities, have high protein content (8.16%) and low-fat content (0.07%) (Thomas *et al*., 2013) [43] as compared with other rice varieties, is gluten-free, gut-friendly and a natural cleaner with many medicinal values (Jha *et al*., 2017) [44]. Black rice contains essential amino acids like lysine, tryptophan, functional lipids, dietary fibre, vitamins such as vitamin B1, vitamin B2, vitamin E, folic acid and phenolic compounds (γ-oryzanols, tocopherols, tocotrienols). It has a mild nutty flavour and is slightly sticky when cooked. It is rich in macro and micro nutrients including iron, zinc, calcium, phosphorus and selenium and low in calories. Black rice is rich in nutrients and protein content compared with the other varieties of rice grown in northeast India. It is often mixed with white rice before cooking to increase flavour, quality and palatability.

Due to higher fiber content it has lower digestibility, takes more time to cook than white rice and feels rubbery while chewing. To overcome this, black rice is parboiled to reduce cooking time and improve the textural quality of grains but color might be lost during this process. In recent time, it has become popular in food, cosmetic, nutraceutical and pharmaceutical applications owing to its numerous health benefits. It is not consumed as staple food but consumed as the functional foods because of its anthocyanin content, acts as major bio-active compound. Accumulation of anthocyanin (Cyanidin-3-glucoside, cyanidin-3-rutinoside, and peonidin-3-glucoside) in the pericarp, tegmen and aleurone layer promotes black color to rice grains. Anthocyanins are water soluble pigment which is responsible for the antioxidative and anti-inflammatory properties of black rice. It has potential use in nutraceutical or functional food formulation. Black rice is a type of pigmented rice with black bran covering the endosperm of the rice kernel. Black rice 'Chakhao' is an aromatic and pigmented rice variety popular in Asia, whose demand and consumption is increasing day by day in India as well as in the world due to its numerous health benefits. Black rice is grown under rainfed condition in both upland and lowland rice ecosystem.

Black and red rice is resistance to insect and pest than the brown rice. In black rice anthocyanins are found in higher concentrations than in dark fruits, such as blueberries, blackberries, dark grapes and dark cherries. Hence, it is better source of antioxidants than blueberry (Kushwaha, 2016) [46]. A recent study reported that pigmentation in black rice results from the activity of the Kala4 gene, which is necessary for anthocyanin synthesis (Pratiwi *et al*., 2017) [48].

The North Eastern Region of India is considered as organic by default owing to the low use of inorganic fertilizers and chemicals. The average NPK fertilizer use in the NER is reported to be 51.67 kg ha^{-1} against the country's average of 144.33 kg ha^{-1} (Anon, 2019) [9]. Except Sikkim and Tripura, all other NER states are having higher share of area under food grain production compared to national average (65 per cent). Assam basically a rice centric state mainly due to the fact that during *kharif* season this state receives heavy rainfall resulting in waterlogging in the low and medium land situations. Under water logged condition, rice is the best suitable crop which provides the advantage of less weed menace. Besides this, majority of the people of the state consume rice as staple food. Hence, under favourable agro-climatic condition, farmers of the state cultivate both traditional and high-yielding varieties of non-aromatic, aromatic and glutinous rice during the *kharif season.* In Assam, rice occupies 4.16 million hectares of land under gross cropped area covering three rice growing seasons of the state *viz., sali* or winter rice, *ahu* or autumn rice and *boro* and early *ahu* or summer rice. Rice alone contributes 96% of food grain production of the state of Assam. The annual rice production in the state is 51.25 million tonnes with an average productivity of 2087 kg ha^{-1} (Anon., 2019) [9].

More focus on recent agronomic intervention like System of Rice Intensification may open new avenue for boosting rice production under organic ecosystems with the traditional varieties. The growth, yield and quality advantages under SRI system may be explored to give organic rice production a new momentum. A shift from traditional to scientific cultivation of organic black rice may enhance the productivity of rice and there by increase income of farmers. Potassium (K) is an essential macro-nutrient required for proper growth and development of plants. Commonly known as the "quality nutrient", K improv resistance to eto several plant diseases. It is also essential for water regulation and maintaining cell wall strength. If K is deficient or not supplied in an adequate amount, growth may stunted and yield could be reduced. In organic farming, proper management of K is very crucial for better crop production, protection and quality of organic foods. It is necessary to supplement the required K through various organic sources so that plants do not have to suffer from deficiency symptoms throughout their growth period. The target of higher yield from traditional black rice may be achieved by adoption of SRI technique along with proper K management practices under organic ecosystem.

2. History

Black rice has been consumed for centuries in Asian countries such as China, Korea and Japan. It has been reported that black rice has greater antioxidant activity than white rice. In Asian countries, China and Indonesia common people were not allowed to store/ cultivate/ consume black rice during imperial period without permission of the authorities and was solely consumed by royals and elite personalities and used as a tribute food. In ancient times it was believed that black rice would increase the life span and good health of king and was considered very superior and rare. Black rice is known by many names such as forbidden rice, imperial rice, king's rice, purple rice, heaven rice and prized rice (Kushwaha, 2016) [46] and is packed with high level of antioxidants and micronutrients. Now, black rice is consumed and grown in many countries. In India, black rice is grown in Manipur on small scale by traditional farmers. China is the richest country in the black rice resources (62%) followed by Srilanka (8.6%), Indonesia (7.2%), India (5.1%), Bangladesh (4.1%) and few in Malaysia (Chaudhary, 2003) [33]. So far they have developed 200 varieties including 52 high yielding varieties (Biswas, 2012) [18].

3. Material and methods

3.1 Experimental site description

The experiment was conducted at certified organic block of the Instructional-Cum Research (ICR) Farm of the Assam Agricultural University, Jorhat during *kharif* season of 2019-20 and 2020-21 under rainfed medium land situation. The farm is located at 26° 47'N latitude and 94° 12'E longitudes at an elevation of about 86.6 m above mean sea level. The topography of experimental field was uniform and fairly levelled. The representative soil samples from 0 to 30 cm depth were taken from randomly selected plots all over the experimental field before laying out the experiment. The soil of the experimental site was sandy loam in texture with pH 5.3, low in available nitrogen (246.45 kg ha^{-1}), phosphorus (21.02 kg ha^{-1}) and available potassium (144.80 kg ha^{-1}) and medium in organic carbon (0.72%). (Table 4.) The total rainfall received was 110.6 mm. in 2019 and 1272.1 mm in 2020 during the cropping period. The cropping history of certified organic experimental plot for last three years is presented in Table 1.

3.2. Experimental details

The experiment consisted of twelve different treatments with alone and combination of organic nutrient sources *viz.*, Control (T_1), Potash solubilizing bacteria (KSB) @ 3.5 kg ha^{-1}

as root dip treatment (T_2), RDK through azolla incorporation (T_3), RDK through water hyacinth incorporation (T_4), RDK through banana pseudo stem vermicompost (T_5), RDK through azolla incorporation + mustard oil cake @ 20 kg ha^{-1} (T_6), RDK through water hyacinth incorporation + mustard oil cake @ 20 kg ha^{-1} (T_7), RDK through banana pseudo stem vermicompost + mustard oil cake @ 20 kg ha^{-1} (T_8), RDK through azolla incorporation +Potash solubilizing bacteria (KSB) @ 3.5 kg ha^{-1} as rood dip treatment (T_9), RDK through water hyacinth incorporation + Potash solubilizing bacteria (KSB) @ 3.5 kg ha^{-1} (T_{10}), RDK through banana pseudo stem vermicompost + Potash solubilizing bacteria (KSB) @ 3.5 kg ha^{-1} (T_{11}), Indigenous traditional knowledge (T_{12}). The experiment was laid out in a Randomized Block Design (RBD) with three replications. The gross size of the area was 563.75 m^2 and net area was 432 m^2. The seeding was raised on nursery bed and after 14 days the seeding were transplanted into main field by keeping 25 cm x 25 cm spacing between plant to plant and between row to row. The individual plant size was 4 m x 3 m. Sowing was done under system of rice intensification. The organic inputs were incorporated into each experimental plot before one month.

3.3. Climatic conditions of experimental field

The experimental site, Jorhat falls in the Upper Brahmaputra Valley Agro-Climatic Zone of Assam. The zone is characterized by a sub-tropical climate with hot humid summer and relatively dry and cold winter. Falling in the south-west monsoon region, it receives total mean annual precipitation of about 2014 mm. Normally, monsoon rain starts from the month of June and continues up to the month of September and sometimes even up to first week of October with the pre-monsoon showers from mid-March to April. The intensity of rainfall decreases from mid of September reaching minimum or zero during December-January. The relative humidity of this zone is high (above 80 per cent) during the *kharif season* as the region is located in sub-tropical humid region. The maximum temperature range is 34-37 °C during summer and the minimum temperature range falls between 8-10 °C during winter. In the first year of experimentation, the mean maximum bright sunshine hours (hours/day) were as high as 8.2 hours /day in the 49 SMW (3 Dec -9 Dec, 2019). The lowest bright sunshine hours were recorded as 1.8 hours/day in the 30 SMW (23-29 July, 2019). The corresponding values for the second year (2020) of experimentation were 7.4 hours/day in the 34 SMW (20 Aug - 26 Aug) and 0.9 hours/day in the 29 SMW (16 July -22 July).

Table 1: Cropping history of experimental field

Year	Kharif	Rabi	Summer
2016-17	Rice	Rice	Fallow
2017-18	Rice	Rice	Fallow
2018-19	Rice	Rice	Fallow
2019-20	Present investigation	Fallow	
2020-21	Present investigation	Fallow	

Table 2: Quantification of N, P and K content in different organic sources (dry weight basis)

Organic sources (Inputs)	Moisture (%)	N (%)	P (%)	K (%)	Quantity (kg ha$^{-1)}$ (Dry weight basis)
i. Azolla	35	2.29	1.00	2.01	770
ii. Water hyacinth	35	0.75	0.32	2.27	685
iii. Banana pseudo stem compost	40	1.54	1.10	2.45	685
iv. Mustard Oil cake	8.75	3.15	1.35	1.00	22
v. Wood ash	6.18	1.40	1.24	2.64	410
vi. Fish wash water	-	0.23	0.12	0.026	10 Lit

Table 3: The classified description of the treatments with corresponding symbol is shown below:

Sl. No.	Treatment	Symbol
1.	Control (No organic nutrient input)	T_1
2.	KSB @ 3.5 kg ha^{-1} as root dip treatment	T_2
3.	RDK through azolla incorporation	T_3
4.	RDK through water hyacinth incorporation	T_4
5.	RDK through banana pseudo vermicompost	T_5
6.	RDK through azolla incorporation + Mustard oil cake @ 20 kg ha^{-1}	T_6
7.	RDK through water hyacinth incorporation + Mustard oil cake @ 20 kg ha^{-1}	T_7
8.	RDK through banana pseudo vermicompost + Mustard oil cake @ 20 kg ha^{-1}	T_8
9.	RDK through azolla incorporation + KSB @ 3.5 kg ha^{-1}	T_9
10	RDK through water hyacinth incorporation + KSB @ 3.5 kg ha^{-1}	T_{10}
11	RDK through banana pseudo stem vermicompost + KSB @ 3.5 kg ha^{-1}	T_{11}
12	ITK (Wood ash + Fish washing water application)	T_{12}

Table 4: Initial soil status of experimental plot

Sl. No	Properties	Composition (Value)	Textural class/stats	Methods adopted
A **Physical property**				
i	Texture			
ii	Sand (%) Silt (%) Clay (%)	59.00 22.12 17.61	Sandy loam	International pipette Method (Piper, 1966) [49]
iii	Bulk density (g cc^{-1})	1.26		Core Sampler Method (Piper, 1966) [49]
iv	Water holding capacity (%)	36.31		Ken Rackzowaski Box Method (Piper. 1966) [66]
B	**B Chemical properties**			
i	pH (Soil reaction)	5.75	Acidic	Glass electrode pH Meter (Jackson, 1973) [45]
ii	Electrical conductivity (EC dsm^{-1})	0.05	Normal	Solubridge Method (Black, 1965) [23]
iii	CEC (meq per 100 of soil)	6.54	Medium	Distillation method (Jackson, 1973) [45]
iv	Organic carbon (%)	0.71	Medium	Walkley and Black's Titration Method (Jackson, 1973) [45]
v	Available N (kg ha^{-1})	244.45	Low	Kjeldahl Method (Jackson, 1973) [45]
vi	Available P2O5 (kg ha^{-1})	19.81	Low	Bray's I Method (Jackson, 1973) [45]
vii	Available K2O (kg ha^{-1})	142.70	Medium	Flame photometric method (Jackson, 1973) [45]
C Microbial properties				
i	Microbial biomass carbon (μg/g dry soil)	558.7		Chloroform fumigation extraction technique (Vance *et al.*, 1987) [54]
ii	Dehydrogenase activity (μg TPF/g/day)	50.64		Reduction of TTC to TPF (Casida *et al.*, 1964) [37]

Data collection

Data on the important biometric observations were collected on five randomly selected and neatly labeled with wooden pegs and taged plants in each treatment throughout the crop life by leaving two border rows, one on each side of plot. These plants were separately harvested at maturity for assessing their yield and yield attributes.

4.Plant growth parameters

4.1. Plant height (cm)

Plant height was measured from the base of the stem to the tip of the youngest leaf using a meter scale and expressed in cm. Plant height was taken at 30, 60 and 90 DAT and the mean was expressed in cm.

4.2. Number of tillers hill^{-1}

Five hills were selected in each plot leaving the border rows of the plot and the total number of tillers of individual hill was counted at 30 days' interval. The average values were recorded and expressed in numbers hill^{-1}.

4.3. Number of leaves hill^{-1}

Five hills were selected in each plot leaving the border rows of the plot and the total number of tillers of individual hill was counted at 30 days' interval. The average values were recorded and expressed in numbers hill^{-1}.

4.4. Dry matter (g plant^{-1})

The weight of dry matter is an index of productive capacity of the plant. Hence one representative plant from each net plot was randomly uprooted at each observation *i.e.* at 30 days' interval and finally at harvest. The roots were washed to remove the soil adhered to the roots and kept for shade drying. After shade drying, the sample was dried in an oven at 65 + 2 °C temperature for 48 hours till the constant weight was obtained. The constant weight was recorded as total dry matter weight (g) per plant for each treatment using electric balance.

4.5. Leaf area index (LAI)

Leaf area index is defined as leaf area (assimilatory source) per unit land area. It was calculated at 30 days' interval as per the formula given by Watson (1952) [55].

$$LAI = \frac{\text{Leaf area hill}^{-1}\ (cm^2)}{\text{Spacing}\ (cm^2)}$$

4.6. Dry matter (g plant^{-1})

The weight of dry matter is an index of productive capacity of the plant. Hence one representative plant from each net plot was randomly uprooted at each observation *i.e.* at 30 days' interval and finally at harvest. The roots were washed to remove the soil adhered to the roots and kept for shade drying. After shade drying the sample was dried in an oven at 65 + 2 °C temperature for 48 hours till the constant weight was obtained. The constant weight was recorded as total dry matter weight (g) per plant for each treatment using electric balance.

4.7. Root volume (Cubic centimetre)

Root volume was determined by water displacement method used by Raja and Bishnoi (1990) [50] and was expressed as cubic centimetre (CC). After measuring the root length of 10 randomly selected seedlings or hills, the root of each treatment was submerged in 200-500 CC water taking in a 1000 CC measuring cylinder, the water raised in the cylinder was noted to measure root volume of the seedling and expressed as cc/hill.

5. Yield and yield attributes

5.1. Panicle length (cm)

Panicle length was measured in centimetres (cm) from the neck joint to the tip of the topmost spikelet of the panicle. Average value from 10 randomly selected panicles in each plot was taken.

5.6. 1000 grain weight

From each net plot harvested, 1000 well-filled grains were counted carefully, separately dried to 14 per cent moisture content and weights were recorded in grams.

5.7. Grain yield
The weight of grains was taken separately for each net plot eliminating the border rows and the row used for sampling of the individual plot and converted to quintals per hectare.

5.8. Straw yield
After threshing, the straw was taken separately for each net plot and after sun drying for 5 days the weights were recorded in kilogram per plot. The kilograms per plot values were converted to quintals per hectare for statistical analysis.

6. Statistical analysis
6.1 Year-wise analysis
All the data pertaining to the present investigation wherever needed were statistically analysed as per the procedure prescribed for randomized block design described by Panse and Sukhatme (1985) [57] to obtain analysis of variance. If the variance ratio (F test) was found significant at 5 per cent level of significance, then standard error of mean (SEm ±) and critical differences were calculated as follows.
The standard error of the difference was calculated by using the following expression:

$$S.Ed(\pm) = \frac{\sqrt{2EMS}}{r}$$

The critical difference (CD) was calculated to find out the significance of mean difference amongst treatment by following formula:

CD = S. Ed x t (Fisher)

Where,
t = Tabulated, t' at 5% level

6.2 Pooled analysis
All the data pertaining to the present investigation wherever needed were statistically analysed as per the method described by Panse and Sukhatme (1985) [57]. Significance or non-significance of the variance due to treatment effects was determined by calculating representative 'R' values.

7. Incorporation of organic inputs
7.1Application of vermicompost by banana pseudo stem
Vermicomposting is the breaking down of organic material through the use of worms, bacteria and fungi. Instead of using regular organic waste material, banana pseudo stem is used as a substrate along with cow dung. This is a nutrient-rich organic substance that can be added to soil to increase its organic matter content and available nutrients. For making banana pseudo stem vermicompost, some locally available banana plants were collected and those plants were chopped with small pieces. After chopping those chopped pieces were dried under shade at A.A.U Vermicomposting unit. The semi dried chopped banana pieces were used for making banana pseudo stem vermicompost. So after that vermicompost made from banana pseudo stem compost were incorporated into treatment allotted plot well before one month of transplanting.

7.2 Incorporation of water hyacinth
Water hyacinth is a free-floating invasive aquatic plant originated from Amazon Basin, South America. It has spread mainly to the tropics and subtropics since the 1800. Water hyacinth has been considered as an invasive aquatic plant in the United States since 1984, in Africa since early 1900, in Asia since 1902, and in Europe since 1930. The water hyacinth was collected from AAU, water pond and dried under shade. The collected water hyacinth was chopped into small pieces and finally incorporated into the field one month before transplanting.

7.3 Incorporation of Azolla
The azolla species *A. Caroliniana* was collected from Azolla production unit of Assam Agricultural University, Jorhat. The collected azolla was sun-dried and after drying that dried azolla was incorporated in field just before one month of transplanting.

7.4 Incorporation of Mustard oil cake (MOC)
The mustard oil cake was brought from an organic farmer from Majuli district of Assam with the help of KVK Jorhat. The organic MOC so collected was processed in the laboratory of Agronomy Department for grinding and subsequent nutrient analysis. The powder form of MOC was applied to the experimental field as per treatment before one month of transplanting.

7.5 Application of wood ash as ITK
The wood ash was collected from a local village Jamukudi, Jorhat. Utmost care was taken to make the wood ash free from foreign materials and inorganic compounds. The collected wood ash was sieved to separate out large objects. The powder form of wood ash was incorporated in the field as per treatment just one month ahead of transplanting.

7.6 Application of fish wash water as ITK
As one of the treatments of present research work, fish washing water was applied to rice at PI stage as foliar spray. Local fish was collected from Majuli district purely reared organically in farm pond without any contaminated water. After collection, fishes were dressed and washed clearly with 1:3 ratio of fish to water and that washed water was collected and stored for one week. The water so collected was sprayed in respective treatment at P.I stage of rice after analysis of nutrient content in the Agronomy laboratory. Traditionally, many farmers and farm women apply wood ash and fish washing water to their kitchen gardens with the believe that they may promote growth of crop with protection from insect pest infestation. Some researchers are also of the opinion that fish washing water and ash may contain high level of K which may have growth promoting effect as believed by traditional farmers. These two ITKs were combined in the treatment to validate their combined effects in organic rice cultivation.

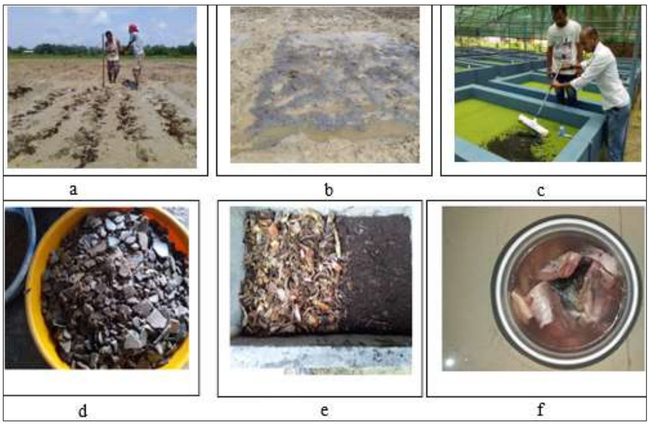

Fig 1: A. before sowing (Azolla incorporation). B. Wood ash incorporation. C. Azolla production. D. Mustard oil cake. E. Banana pseudo stem vermicompost. F. Fish wash water

8. Results and Discussion

Plant height (cm), Number of leaves hill^{-1}, Leaf area index, Root volume (cm^3), Dry matter accumulation (g) hill were considered as the growth parameters of the black rice.

8.1 Plant height (cm)

Data revealed that the plant height was progressively increased with advancement in age of the crop and reached its maximum height at harvest. The tallest plants during 2019 and 2020 at harvest stage were 181.14 cm and 184.31 cm, respectively with application of RDK through azolla incorporation + mustard oil cake @ 20 kg ha^{-1} (T_6) which was found at par with treatment T_9 (RDK through azolla incorporation along with potash solubilising bacteria @ 3.5 kg ha^{-1} as root dip treatment) and T_3 (RDK through azolla incorporation) during both the years of study. The least height of plant was observed with control (141.18 cm) and (142.80 cm) during both the cropping years. The increased plant height recorded under different organic inputs might be due to increased availability of essential plant nutrients *i.e.* Nitrogen, phosphorus, potassium with addition of banana pseudo stem vermicompost and bio-fertilizer seedling root dip treatment. The variation in plant may be due to variation in nutrient content in applied organic sources and also the variation in availability of the nutrients.

8.2 Number of leaves hill^{-1}

Leaves are the complex plant organ upon which life of plant depends and able to capture solar energy and form sugar molecules that are constructed from carbon dioxide and water by the process of photosynthesis. Hence, more food was produced for translocation to different parts of the plant. Also, their number over plant directly indicates the behavioural adaptation due to changes in the nutritional supply capacity of the soil, keeping the other entire factor constant. Hence, during present investigation, the number of leaves hill^{-1} were counted. The combine application of RDK through banana pseudo stem vermicompost and mustard oil cake @ 20 kg ha^{-1} (174,66) and (181,66) T_8 recorded elevated values for number of leaves during both the years. However, statistically similar but numerically different values were obtained with combined application of T_6 (RDK through azolla incorporation + mustard oil cake @ 20 kg ha^{-1}), T_7 (RDK through water hyacinth incorporation + mustard oil cake @ 20 kg ha^{-1}), T_{11} (RDK through banana pseudo stem vermicompost + potash solubilising bacteria @ 3.5 kg ha^{-1}), during 2019 and 2020. These happen because crop receives nutrients and moisture for longer period of time due to application of nutrients through organic sources in split form, that enhanced crop growth by cell division in the meristematic region and by increased activity of the growing tip of the crop by increasing interception of more photosynthetically active radiations owing to better geometric situation that might have resulted in vigorous plant growth and more number of branches and leaves.

8.3 Leaf area index

The application of RDK through banana pseudo stem vermicompost + mustard oil cake @ 20 kg ha^{1} (T_8) produced the highest leaf area index (5.48 during 2019 and 5.54 during 2020) however it was found to be statistically at par with T_6 (RDK through azolla incorporation + mustard oil cake @ 20 kg ha^{-1}), T_7 (RDK through water hyacinth incorporation + mustard oil cake @ 20 kg ha^{-1}) and T_{11} (RDK through banana pseudo stem vermicompost + potash solubilising bacteria @ 3.5 kg ha^{1}). The lowest LAI (4.12) and (4.18) was observed with control (T^1) during both the cropping years.

8.4 Root volume (cm^3)

Data pertaining to root volume (cm^3 plant^{-1}) as significantly influenced by different K management practices during both the years of the study are presented in Table 5. Data revealed that, rate of increase in root volume of black rice (cm^3 plant^{-1}) was increased rapidly up to 120 DAT and thereafter, rate was slightly slowed down with the decreasing rate up to physiological maturity. With application of RDK through banana pseudo stem vermicompost + mustard oil cake @ 20 kg ha^{-1} treatment (T_8) registered significantly superior with respect to highest root volume (352.12cm^{-3}) and (354.18 cm^{-3}) respectively during both the years which was found statistically at par with T_6 treatment over rest of all treatment. Significantly lowest root volume (168.58 cm^{-3}) and (172.36 cm^{-3}) of black rice was recorded in treatment T_1 (Control) during 2019-2020. The highest root volume under treatment T_8 receiving RDK through banana pseudo stem vermicompost along with mustard oil cake @ 20 kg ha^{-1} might be due to more favourable plant root environment due to adaptation of system of rice intensification with addition of nutrient through banana pseudo stem vermicompost which is a powerhouse of many essential plant nutrient and growth-promoting enzymes.

8.5 Dry matter accumulation (g) hill^{-1}

The perusal of the data given in Table 5. showed that, application of RDK through banana pseudo stem vermicompost + mustard oil cake @ 20 kg ha^{-1} (T_8) reported significantly higher dry matter accumulation (g) hill^{-1} during both the years from 30 DAT up to harvesting over rest of treatments at all crop growth stages except at 30 DAS during the year 2019 and 2020. The higher dry matter accumulation (225.64 and 231,91 g) hill^{-1} was observed during 2019 and 2020 with application of RDK through banana pseudo stem vermicompost + mustard oil cake @ 20 kg ha^{-1} (T_8) which was found statistically at par with T_6 (RDK through azolla incorporation + mustard oil cake @ 20 kg ha^{-1}), T_7 (RDK through water hyacinth incorporation + mustard oil cake @ 20 kg ha^{-1}) and T_{11} (application of RDK through banana pseudo stem vermicompost + potash solubilising bacteria @ 3.5 kg ha^{-1}) at 120 DAT and at physiological maturity during 2019 and 2020. Significantly the lowest dry matter accumulation (g plant^{1}) was produced under T_1 treatment.

Table 5: Effect of different K management practices on growth attributes of organic black rice

Treatment	plant height (cm)		Number of leaves hill^{-1}		Leaf area index		Root volume (cm^3)		Dry matter accumulation (g) hill^{-1}	
	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
T_1	141.18	142.80	149.09	156.09	4.12	4.18	168.58	172.36	144.71	148.32
T_2	147.14	149.12	153.10	160.10	4.34	4.40	196.68	199.12	153.51	160.22
T_3	178.13	181.31	159.58	166.58	4.45	4.54	216.78	220.68	177.97	178.12
T_4	149.59	151.42	157.39	164.39	4.39	4.48	210.22	214.42	172.57	175.93
T_5	167.06	169.12	162.48	169.48	4.56	4.64	230.84	234.54	178.04	181.28
T_6	181.14	184.31	172.64	179.64	5.38	5.45	316.18	322.64	218.66	225.87
T_7	156.22	158.25	170.24	177.24	5.24	5.30	285.10	292.42	211.69	216.22
T_8	172.13	175.21	174.66	181.66	5.48	5.54	352.12	354.18	225.64	231.91
T_9	179.21	182.22	167.45	174.45	5.04	5.10	258.24	262.38	198.60	206.12
T_{10}	153.18	155.08	165.18	172.18	4.86	4.92	244.64	248.52	188.22	191.18
T_{11}	171.30	174.44	168.89	175.89	5.16	5.22	272.34	276.24	208.75	212.38
T_{12}	164.54	166.32	163.74	170.74	4.64	4.72	235.48	238.28	185.26	189.61
S.Ed(±)	6.67	6.24	5.18	5.22	0.30	0.31	15.68	15.97	6.81	6.66
CD at 5%	18.55	18.31	10.19	10.31	0.57	0.61	45.99	46.83	19.98	19.53
CV (%)	6.96	6.43	5.48	5.30	10.95	10.95	10.91	10.93	6.26	5.97

8.6 Number of panicles m^{-2}

The highest number of panicles m^{-2} (294.10) in 2019 and (305.20) in 2020 was recorded under T_8 treatment with application of (RDK through banana pseudo stem vermicompost + mustard oil cake @ 20 kg ha^{-1}) during 2019 and 2020 which was found statistically at par with T_6 treatment (RDK through azolla incorporation + mustard oil cake @ 20 kg ha^{-1}), T_7 (RDK through water hyacinth incorporation + mustard oil cake @ 20 kg ha^{-1}), T_{11} (RDK through banana pseudo stem vermicompost + potash solubilising bacteria @ 3.5 kg ha^{-1} as root dip treatment). However, the lowest number of effective tillers hill^{-1} (164.20) during 2019 and (167.00) during 2020 were registered in control. This highest number of panicles m^{-2} under treatment T_8 may be attributed due to supply of balanced amount of all essential nutrients through banana pseudo stem vermicompost.

8.7 Panicle length (cm)

Reproductive stage is the ultimate goal of famers and scientist as well in which length of panicle is important parameters that directly influences the yield. In the present study, the panicle length of black rice crop was significantly influenced by different K management practices. The variations in length of panicle due to various organic inputs were found significant during both the years of study. Under treatment T_8 (RDK through banana pseudo stem compost along with mustard oil cake @ 20 kg ha^{-1}) produced the highest panicle length (27.49 cm) during 2019 and (28.87 cm) during 2020 respectively. both the years of experimentation, however, it was found statistically at par with T_6, T_7 and T_{11}. The lowest panicle length (18.48 cm) and (22.07 cm) observed under treatment T_1 (Control) during both years. The highest value under treatment T_8 may be the result of more readily availability nutrients through organic sources.

8.8 1000-grain weight (g)

The highest values of test weight24.48 and 24.56 during both the cropping years were recorded in the T_8 treatment with application of RDK through banana pseudo stem vermicompost + mustard oil cake @ 20 kg ha^{-1} during both the years of experimentation. The significant reduction in 1000 grain weight under the control may be attributed to the deficiency of the plant nutrients at the time of grain filling. The decrease in test weight of rice under lower level of nutrients was earlier reported by Bora *et al*. (2014) [24] and Gangmei and George (2017) [40].

8.9 Grain yield (q ha^{-1})

Perusal of the data on seed yield of black rice (q ha^{-1}) during first and second year are tabulated in Table 6. All the treatments were found to be significantly superior over the control during both the years. With application of RDK through banana pseudo stem vermicompost along with mustard oil cake @ 20 kg ha^{-1}) recorded significantly more grain yield 23.99 q ha^{-1} during 2019 and 25.05 q ha^{-1} during 2020 which was found statistically at par with T_6 treatment (RDK through azolla incorporation + mustard oil cake @ 20 kg ha^{-1}), T_7 (RDK through water hyacinth incorporation + mustard oil cake @ 20 kg ha^{-1}) and T_{11} (RDK through banana pseudo stem vermicompost + potash solubilising bacteria @ 3.5 kg ha^{-1} as root dip treatment) respectively. The lowest grain yield 12.75 q ha^{-1}and 13.05 was recorded with T_1 treatment during both the years. The increased grain yield recorded in the treatment T_8 with application of RDK through banana pseudo stem vermicompost along with mustard oil cake @ 20 kg ha^{-1} might be due to significantly higher yield attributes, good crop conditions and efficient utilization of resources recorded under this treatment. The entire K management practice resulted boost in productivity in the second year. The control plot recorded the lowest yield but marginal boost in productivity was noticed in the second year. RDK through banana pseudo stem vermicompost along with mustard oil cake resulted maximum availability of nutrients which maintained a favourable soil physical, chemical and biological environment. Vermicompost is much known for nutrient content. Many beneficial micro floras such as nitrogen fixers and biologically active metabolites like gibberellins, cytokinins, auxins and group B vitamins which increases the availability of nutrients. The potash solubilising bacteria applied through the root dip treatment increased the solubility of insoluble potash through the production of organic acids, citric acids, malic acid and propionic acids. These acids facilitate mobilization of soil potassium and increased potassium availability in soil ecosystem. The organic inputs as a whole improved the soil support system and ensured nutrient availability which was ultimately reflected in yield performances of the crop. This result is in the agreement with the findings of Kumar *et al*. (2017) [58] and Yadav *et al*. (2013) [56].

8.10 Straw yield (q ha^{-1})

Data presented in Table 6. regarding straw yield (q ha^{-1}) as influenced by different K management practices during both the years of study. During both the year, all the organic treatments were found to be significantly superior over the control treatment. Among the treatments, higher straw yield was recorded under T_8 (RDK through banana pseudo stem vermicompost + mustard oil cake @ 20 kg ha^{-1}) *i.e.* 45.02 during 2019 and 47.12 q ha^{-1} during 2020 which was found statistically at par with treatment T_6in (RDK through azolla incorporation + mustard oil cake @ 20 kg ha^{-1}), T_7(RDK through water hyacinth incorporation + mustard oil cake @ 20 kg ha^{-1}), T_{11}(RDK through banana pseudo stem vermicompost + potash solubilising bacteria @ 3.5 kg ha^{-1} as root dip treatment). Significantly lower straw yield 31.23 q ha^{-1}during2019 and 32.05q ha^{-1}during 2020 was recorded under T_1 treatment (Control). The increased straw yield due to the organic nutrient sources might be attributed to the higher growth parameters of the black rice recorded in the treated plots.

Table 6: Yield and yield attributes of organic black rice as influenced by different K management practices

Treatment	Number of panicles m^{-2}		Panicle length (cm)		1000-grain weight (g)		Grain yield (q ha^{-1})		Straw yield (q ha^{-1})	
	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
T_1	164.20	167.00	18.48	22.07	18.09	18.43	12.75	13.05	31.23	32.05
T_2	196.12	201.50	20.20	23.90	18.52	18.85	14.35	15.38	33.32	34.75
T_3	224.31	228.11	22.33	25.49	19.71	20.05	16.41	17.97	36.91	37.85
T_4	209.52	212.00	21.61	25.15	19.13	19.20	15.55	16.55	35.78	36.64
T_5	232.18	235.67	22.78	25.64	20.33	20.40	18.54	19.50	37.75	38.82
T_6	264.30	271.10	26.55	27.80	21.96	22.11	22.92	24.52	44.05	45.84
T_7	261.40	268.91	25.81	27.17	21.80	21.98	22.32	24.32	43.54	44.89
T_8	294.10	305.20	27.49	28.87	24.48	24.56	23.99	25.05	45.02	47.12
T_9	248.13	252.33	24.64	26.57	20.87	20.87	21.21	23.16	40.59	42.48
T_{10}	245.16	248.67	24.19	26.01	20.54	20.60	19.56	21.37	39.43	40.84
T_{11}	256.21	262.78	25.23	26.87	21.73	21.76	21.98	23.80	42.06	44.24
T_{12}	236.10	240.00	23.74	25.98	20.53	20.58	19.08	20.62	38.48	39.68
S.Ed(±)	14.90	14.67	1.49	1.08	0.25	0.26	1.20	1.29	2.46	2.55
CD at 5%	43.69	43.02	2.71	2.30	0.73	0.78	2.80	3.50	5.23	7.49
CV (%)	10.93	10.54	10.95	7.18	2.09	2.21	10.87	10.91	10.94	10.93

References

1. Abdel-Aal ESM, Young JC, Rabalski I. Anthocyanin composition in black, blue, pink, purple, and red cereal grains. Journal of agricultural and food chemistry. 2006;54(13):4696-4704.
2. Ahmed SA. M.Sc. (Agri.) Thesis, Assam Agricultural University, Jorhat; c1993.
3. Ahmed SA, Baruah I, Sarkar CR, Thakur AC. Volatile component (2-acetyl-1-pyroline) in scented rice. Proc. of the seminar on Problem and Prospect of Agricultural Research and Development in North-East India. Assam Agril. University, Jorhat, India; c1996. p. 55-57.
4. Ahuja U, Ahuja SC, Thakrar R, Rani N. Scented rice of India. Asian Agri-History. 2008;12(4):267-283.
5. Aleksandrov V, Blagodyr R, Ilev I. Liberation of phosphoric acid from apatite by silicate bacteria. Mikrobiolohichni zhurnal Z. 1967;29:111-114.
6. Ali RI, Awan TH, Ahmad M, Saleem MU, Akhtar M. Diversification of Rice-based Cropping systems to improve soil fertility, sustainable productivity and economics. The journal of Animal and Plant Sciences. 2012;22(1):108-112
7. Amtmann A, Hammond JP, Armengaud P, White PJ. Nutrient sensing and signalling in plants: potassium and phosphorus. Adv. Bot. Res. 2006;43:209-257.
8. Amtmann A, Troufflard S, Armengaud P. The effect of potassium nutrition on pest and disease resistance in plants. Plant Physiol. 2008;133:682-691.
9. Anonymous, Directorate of Economics and Statistics, Govt. of Assam; c2019.
10. Anonymous, Directorate of Economics and Statistics, Department of Agriculture and Co-operation, Ministry of Agriculture, Government of India; c2020.
11. Asamarai AM, Addis PB, Epley RJ, Krick TP. Wild rice hull antioxidants. Journal of Agricultural and Food Chemistry. 1996;44:126-130.
12. Ashraf M, Mohmood T, Azman F, Qureshi RM. Comparative effects of applying leguminous and non-leguminous green manure crop and inorganic N on the biomass yield and nitrogen uptake in flooded rice. J Biol. Fretil. Soil. 2004;40:47-152.
13. Aziz T, Ullah S, Sattar A, Nasim M, Farooq M, Mujtabakhan M. Nutrient availability and maize (*Zea mays*) growth in soil amended with organic manures. Int J Agric. Biol. 2010;12:621-624.
14. Balamurali P. Influence of organic farming and integrated nutrient management practices on short grain scented rice. M.Sc. (Agri.) Thesis, Tamil Nadu Agricultural University, Coimbatore (TN); c2006.
15. Banerjee B, Ghosh M, Pal SK, Mazumdar D, Mahata D. Effect of organic nutrient management practices on yield and economics of scented rice Gobindabhog. *Oryza*. 2013;50(4):365-369.
16. Barik T, Sahu S, Garnayak LM, Gulati JML, Bastia DK. Split application of vermicompost and its effect on growth and yield of organic rice. *Oryza*. 2017;48(3):226-232.
17. Barre P, Montagnier C, Chenu C, Abbadie L, Velde B. Clay minerals as a soil potassium reservoir: observation and quantification through X-ray diffraction. Plant and Soil. 2008;302:213-220.
18. Basak B, Biswas D. Modification of waste mica for alternative source of potassium: evaluation of potassium release in soil from waste mica treated with potassium solubilising bacteria (KSB). LAMBERT Academic Publishing, Germany; c2012. p. 25-141.
19. Basak BB, Biswas DR. Influence of potassium solubilizing microorganism (*Bacillus mucilaginous*) and

waste mica on potassium uptake dynamics by sudan grass (*Sorghum vulgare* Pers.) grown under two Alfisols. Plant and Soil. 2009;317:235-255.
20. Basumatary A, Talukdar M. Status of DTPA extractable micronutrients in soil under rice and sugarcane ecosystems Golaghat district in Assam. J Indian Soc. Soil Sci. 1998;57(3):313-316.
21. Bharadwaj V, Omanwar PK. Long-term effect of continuous rotational cropping and fertilization on crop yields and soil properties-II. Effect on EC, pH, organic matter and available nutrients of soil. J Indian Soc. Soil Sci. 1994;42:387-392.
22. Beiderbecke VO, Zentner RP, Campball CA. Soil bicrobial population and activities as influenced by legume green fallow in semi-arid climate. J Soil. Biol. Biochem. 2005;37(10):1775-84.
23. Black CA. Method of soil analysis American Agronomy Inc., Madison, Wisconsin, USA; c1965. p. 131-137.
24. Bora D, Goswami J, Saud RJ, Begum M. Effect of organic inputs on production and quality of scented rice (*Oryza sativa* L) variety Keteki Joha in Assam and its economic aspect. Agricultural Research Communication Centre journal. 2014;34(2):115-118.
25. Bridle P, Timberlake CF. Anthocyanins as natural food colours-selected aspects. Food chemistry. 1997;58(1-2):103-109.
26. Buchan D, Gebremikael MT, Ameloot N, Sleutel S, De Neve S. The effect of free-living nematodes on nitrogen mineralisation in undisturbed and disturbed soil cores. Soil Biol. Bio chem. 2013;60:142-155.
27. Buragohain. Isolate and characterize the potassium-solubilising bacteria from crop rhizosphere of Assam. M.Sc. (Agri.) Thesis submitted to Assam Agricultural University, Jorhat-13 (Unpublished); c2015.
28. Butelli E, Titta L, Giorgio M, Mock HP, Matros A, Peterek S, *et al*. Enrichment of tomato fruit with health-promoting anthocyanins by expression of select transcription factors. Nature biotechnology. 2008;26(11):1301-1308.
29. Buttery RG, Ling LC, Mon TR. Quantitative analysis of 2-acetyl-1pyrroline in rice. J Agril. Food Chem. 1986;34:112-114.
30. Casida LE, Klein DA, Santoro T. Soil dehydrogenase activity. Soil Sci. 1964;98:371-376.
31. Chaudary RC, Tran DV. Specialty Rice of the World: A Prologue. In: Specialty Rice of the World; Breeding, Production and Marketing. Enfield, N.H. (USA): Science Publishers. Inc. and FAO; c2001. p. 3-12.
32. Chaudary RC. Speciality ices of the world. Effect of WTO and IPR on its production trend and marketing. Journal of Food, Agricultural and Environment. 2003;1(2):34-41.
33. Chaudhary RC. Speciality rices of the world: effect of WTO and IPR; c2003.
34. Chauhan AK, Das A, Kharkwal H, Kharkwal AC, Verma A. Impact of microorganisms on environment and health. In: Microbes health and environment. UK; c2006. p. 1-12.
35. Chen PN, Kuo WH, Chiang CL, Chiou HL, Hsieh YS, Chu SC. Black rice anthocyanins inhibit cancer cells invasion via repressions of MMPs and u-PA expression. Chemico-Biological Interactions. 2006;163(3):218-229.
36. Choi S, Seo HS, Lee KR, Lee S, Lee J, Lee J. Effect of milling and long-term storage on volatiles of black rice (*Oryza sativa* L.) determined by headspace solid-phase micro extraction with gas chromatography-mass spectrometry. Food chemistry. 2019;276:572-582.
37. Casida LE, Klein DA, Santoro T. Soil dehydrogenase activity. Soil Sci. 1964;98:371-376.
38. Doran I, Sen B, Kaya Z. The effects of compost prepared from waste material of banana on the growth, yield and quality properties of banana plants. J Environ. Biol. 2005;26(1):7-12.
39. FAO, International year of rice. Food and Agricultural Organization. Rome; c2018. http://www.fao.org/rice 2004.
40. George PJ, Gangmei TP. Black rice cv. ‘Chakhao Amubi’ (*Oryza sativa* L.) response to organic and inorganic sources of nutrients on growth, yield, and grain protein content. Journal of Pharmacognosy and Phytochemistry. 2017;6(4):550-555.
41. Gomez KA, Gomez AA. Statistical procedures for agricultural research, 2nd Edn., John Wiley and Sons, New York; c1984. p. 704.
42. Hou F, Zhang R, Zhang M, Su D, Wei Z, Deng Y, *et al*. Hepatoprotective and antioxidant activity of anthocyanins in black rice branon carbon tetrachloride-induced liver injury in mice. Journal of Functional Foods. 2013;5(4):1705-13.
43. Thomas R, Wan-Nadiah WA, Bhat R. Physiochemical properties, proximate composition, and cooking qualities of locally grown and imported rice varieties-marketed in Penang, Malaysia. International Food Research Journal, 2013, 20(3).
44. Jha P, Das AJ, Deka SC. Optimization of ultrasound and microwave-assisted extractions of polyphenols from black rice (*Oryza sativa* cv. Poireton) husk. Journal of food science and technology. 2017;54:3847-3858.
45. Jackson ML. Soil chemical analysis. Prentice Hall of India Pvt. Ltd. New Delhi; c1973.
46. Kushwaha UKS. Black rice anthocyanin content increases with increase inaltitude of its plantation. Advances in Plants and Agriculture Research. 2016;5(1):1-4.
47. Lindsay WL, Norvell WA. Development of DTPA soil test for Zn. Fe, Mn and Cu. Soil Science Society of America Journal. 1978;42:421-428.
48. Pratiwi R, Purwestri YA, Apridamayanti P, Tunjung WAS, Rumiyati R. Anthocyanin, nutrient contents, and antioxidant activity of black rice bran of *Oryza sativa* L. ‘Cempo Ireng’ from Sleman, Yogyakarta, Indonesia. Indonesian Journal of Biotechnology. 2017;22(1):49-54.
49. Piper CS. Soil and plant analysis. Hans Publication, Bombay. 3rd Ed; c1966. p. 49-54.
50. Raja V, Bishnoi KC. Evapotranspiration, water use efficiency, moisture extraction pattern and plant water relations of rape (*Brassica campestris*) genotypes in relation to root development under varying irrigation schedules. Experimental Agriculture. 1990;26(2):227-233.
51. Ram M, Davari MR, Sharma SN. Effect of organic manures and biofertilizers on basmati rice under organic farming of rice-wheat cropping system. International Journal of Agriculture and Crop Science. 2011;3(3):76-84.
52. Singh YV, Singh BV, Pabbi S, Singh PK. Impact of

organic farming on yield and quality of basmati rice and soil properties. Paper presented at Zwischen Tradition and Globalisierung -9. Wissenschaftstagung Okologischer Landbau, Universidad Hohenheim, Stuttgart, Deutschland, Germany, during 20-23 March 2007; c2007.
53. Sadasivam S, Manickam A. Biochemical methods. 2nd Ed., New Age International Publishers; c1996. p. 107-109.
54. Vance ED, Brookes PC, Jenkison DS. Chloroform fumigation direct extraction procedure. Soil Biol. Bio chem. 1987;19(6):703-70
55. Watson DJ. Adv. Agron. 1952;4:101-145.
56. Yadav SK, Babu S, Singh Y, Singh K, Singh R, Singh H. Effect of organic nitrogen sources and biofertilizers on production potential and energy budgeting of rice (*Oryza sativa*)-based cropping systems. Indian Journal of Agronomy. 2013;58(4):4509.
57. Panse VG, Sukhatme PV. Statistical methods for agricultural research. ICAR, New Delhi. 1985;8:308-18.
58. Kumar S, Soukup M, Elbaum R. Silicification in grasses: variation between different cell types. Frontiers in Plant Science. 2017 Mar 28;8:438.